Electronic Version

Stylesheet Version v1.1.1

Description

METHOD AND SYSTEM TO CONTROL AMPERAGE TO A SUBSYSTEM COMPONENT RATED AT ONE VOLTAGE IN A SYSTEM OPERATING AT ANOTHER VOLTAGE

BACKGROUND OF INVENTION

[0001] The present invention relates generally to internal combustion engines and, more particularly, to a method and apparatus to control operation of an oil delivery system such that the oil delivery system is operable at an input voltage that exceeds its rated operational voltage.

[0002] As a result of more stringent environmental concerns, desire for improved fuel efficiency, reduced noise emission, consumer desire for more robust operation, and the like, engine design and operation has become increasingly more complex. Contributing to this increased complexity is the incorporation of additional mechanical and elec-

tronic components to control operation of the engine and its components. The advent of additional electronic components to control engine operation has greatly increased the electrical load placed on the engine. This is particularly relevant for engines of recreational products such as outboards, motorcycles, ATVs, snowmobiles, PWCs, and lawn and garden equipment.

[0003] Some modern engines, such as the EVINRUDE outboard motor, have fuel injectors that are designed to operate at rather high voltages that exceed that which can be provided by a 12 volt battery and alternator. EVINRUDE is a registered trademark of the present assignee. These injectors operate extremely fast and responsive, and are not only state-of-the-art in terms of performance, they are so highly tuned that engines so equipped greatly exceed environmental emissions standards for years to come. However, to obtain such exacting performance, the injectors operate at a rather high voltage, preferably 55 volts.

[0004] To meet the electrical requirements of these and other modern engines, larger batteries and/or alternators may be designed to produce more current at a standard voltage level; however, such alternators are large, heavy, and relatively expensive. It is also possible, more practical,

and more robust to provide a power source capable of outputting higher voltages for power the engine and its components. It can be problematic, however, in that most engine components are not rated to operate at the increased voltages output by the power source. As such, while some of the engine components optimally run on at an increased voltage, other engine components are not rated to operate at the increased voltage.

[0005] Simply, the total electrical load of the engine requires more than 12 or 24 volts for optimal engine operation, but a number of engine components are inoperable at voltages substantially exceeding 12 or 24 volts. While these components could be constructed to operate at the higher voltages, such components would be very costly. Rather it is desirable to use standard off-the-shelf components whenever possible. These components are all traditionally 12 volts and some are rated to operate at 24 volts. A number of engine components are preferably 12 or 24 volt rated and are able to withstand voltages nominally above 12 or 24 volts for short periods of time before overheating and failure. Two such engine components include the fuel pump and oil pump of a two-cycle internal combustion engine which are customarily designed to op-

erate with a nominal 12 or 24 volt input. As such, simple incorporation of 12 or 24 volt-rated components into an engine or motor designed to operate a rail voltage substantially greater than 12 or 24 volts is problematic and not feasible. Moreover, off-the-shelf engine components are typically rated to operate at a nominal 12 or 24 volts. Since 12 or 24 volt-rated engine components have been widely accepted and widely available in the marketplace, it would also be difficult to require a conversion to higher rated voltage components.

[0006] It would therefore be desirable to design a system that allows use of standard, off-the-shelf components to be operable with an engine designed to operate at a rail voltage that substantially exceeds the rated operational voltage of the standard engine component. It would also be desirable to design the engine component to be operable at variable voltages above its rated operational voltage.

BRIEF DESCRIPTION OF INVENTION

[0007] The present invention relates to controls designed to allow operation of engine components at input voltages that exceed their rated or maximum operational voltages that overcome the aforementioned drawbacks.

[0008] An engine control is presented that dynamically controls

operation of an engine component, e.g. fuel pump assembly or oil pump assembly, so that the engine component is operable at voltages that exceeds its rated or maximum operational voltage. The engine control monitors the rail voltage provided by an engine's energy source and dynamically controls the engine component to be operable at that rail voltage. In this regard, the engine component is controlled to be operable at voltages exceeding its rated or maximum operational voltage, but is also controlled to be operable at varying voltages above its rated maximum. As such, the engine component is controlled to be functional despite fluctuations in the engine's rail voltage. Accordingly, the engine component is controlled to operate independent of its input voltage.

[0009] Therefore, in accordance with one aspect, the present invention includes an oil delivery system having an oil pump rated to operate within a prescribed voltage range and configured to delivery oil to an internal combustion engine. The oil delivery system also includes a voltage source having an output voltage outside the prescribed voltage range of the oil pump. The system further includes a control connected to the oil pump to operate at the output voltage outside the prescribed voltage range..

[0010] According to another aspect, a control unit includes a drive circuit connected to an engine component rated to operate at a prescribed amperage with a prescribed voltage. The engine component is connected to a voltage rail capable of having a rail voltage greater than the prescribed voltage. The control unit further includes a voltage sensing circuit connected to measure the rail voltage. A control circuit is provided and connected to the voltage sensing circuit and the drive circuit to control the drive circuit to maintain operation of the engine component at approximately the prescribed amperage based on a difference of the prescribed voltage and the rail voltage.

[0011] In accordance with yet another aspect of the invention, an outboard motor is presented that includes an internal combustion engine to provide thrust to propel a watercraft and an engine component in operable association with the internal combustion engine. The engine component is rated to operate at a rated maximum voltage. The outboard motor further includes an engine control unit to control the engine component to operate at a voltage that exceeds the rated maximum voltage of the engine component.

[0012] Various other features, objects, and advantages of the

present invention will be made apparent from the following detailed description and the drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0013] The drawings illustrate the best mode presently contemplated for carrying out the invention.

[0014] In the drawings:

[0015] Fig. 1 is a perspective view of an exemplary outboard motor incorporating the present invention.

[0016] Fig. 2 is a block diagram of an electrical system for an electronically controlled engine according to one aspect of the present invention.

[0017] Fig. 3 is a schematic of a fuel pump control circuit in accordance with one aspect of the present invention.

[0018] Fig. 4 is a schematic of an oil pump control circuit in accordance with another aspect of the present invention.

DETAILED DESCRIPTION

[0019] The present invention relates generally to internal combustion engines, and preferably, to those whose operations are controlled by an engine management module (EMM), or more generally, by a control unit or ECU. Fig. 1 shows an outboard motor 10 having an engine 12 controlled by a control unit 14 mounted directly to the engine

under engine cover 16. Engine 12 is housed generally in a powerhead 18 and is supported on a mid-section 20 configured for mounting on a transom 22 of a boat 24 or other water-going vessel in a known conventional manner. Engine 12 is coupled to transmit power to a propeller 26 to develop thrust and propel boat or other watercraft 24 in a desired direction. The motor 10 includes a lower unit 30 having a gear case 32 that includes a bullet or torpedo section 34 formed therein and housing a propeller shaft 36 that extends rearwardly therefrom. Propeller 26 is driven by propeller shaft 36 and includes a number of fins 38 extending outwardly from a central hub 40 through which exhaust gas from engine 12 is discharged via mid-section 20. A skeg 42 depends vertically downwardly from torpedo section 34 to protect propeller fins 38 and encourage the efficient flow of outboard motor 10 through water. One skilled in the art will appreciate that engine 12 may be either a two-cycle or a four-cycle internal combustion engine; however, in a preferred embodiment, engine 12 is a two-cycle engine that may be used in various modalities that include an outboard motor, snowmobile, ATV, PWC, motorcycles, scooters, or various lawn and garden applications and equipment. Additionally, the

engine may be electronically started or rope started.

[0020] Moreover, while many believe that two-stroke engines are generally not environmentally friendly engines, such preconceptions are misguided in light of contemporary two-stroke engines. Modern direct injected two-stroke engines and, in particular, EVINRUDE outboard motors, are compliant with not only today's emission standards, but emissions standards well into the future. However, since these engines are so advanced, they require trained technicians perform certain repairs and adjustments. As such, a significant portion of the ability to manipulate the operation of these motors has been restricted to qualified personnel in an effort to ensure the future emission efficiency of the engines. Further, the illustrated outboard motor has fuel injectors that are extremely fast and responsive. These injectors are not only state-of-the-art in terms of performance, they are so highly tuned that engines so equipped greatly exceed environmental emissions standards for years to come. To obtain such exacting performance, the injectors operate at a rather high voltage, preferably 55 volts.

[0021] Referring now to Fig. 2, the electrical and electronics system 48 of motor 10 is schematically shown. The electrical

system includes an energy source assembly 50 that includes a permanent magnet alternator 52 and a computer controlled switching regulator 54 to provide electrical power to the motor's electronics. In accordance with well-known alternator operation, the alternator 52 produces alternating current (AC) 55 by converting the engine's mechanical energy into alternating electrical current during engine operation. In this regard, a portion of the mechanical energy generated by the engine crankshaft during engine operation is translated to the alternator 52 for generation of AC. One skilled in the art will readily appreciate that alternators typically comprise a stator (not shown) and a flywheel (not shown) having magnets (not shown) that is driven, directly or indirectly, by the engine's crankshaft. Engine electronics generally operate with direct current (DC), therefore, an AC to DC converter is customarily used to condition the AC signal generated by the alternator to provide a DC signal usable by the engine electronics. In a preferred embodiment however, a computer controlled switching regulator 54 converts the AC output of the alternator 52 into DC. In this regard, the regulator 54 is controlled by a dedicated control unit 56 or is controlled by the ECU.

[0022] The regulator 54 is controlled to provide a DC signal at a desired rail voltage, generally referenced 58, that is used to provide power to the various electronics of the motor. In one embodiment, the regulator is dynamically controlled to provide a rail voltage ranging from 12 to 60 volts and, preferably, to provide a 55 volt rail voltage for powering the motor's electronics. While it is customary to provide a 12 volt rail voltage, engine operation is optimized with a rail voltage greater than 12 volts. However, as will be described, some of the motor's electronics may not be rated to operate at a voltage greater than 12 volts. As such, the present invention includes a control system for controlling operation of a seemingly-incapable component, e.g. a fuel or oil pump, to be operational and functional with a rail voltage that exceeds the component's rated or maximum operational voltage. It is also contemplated that a voltage sensing circuit 60 may be incorporated to provide voltage feedback 62 to a control unit 56 so that the control unit may regulate engine and motor operation dynamically based on the rail voltage output by the switching regulator 54. As will be described however, an engine component may have a dedicated drive circuit that controls operation of an engine compo-

nent based on the rail voltage of the electrical system independent, or in conjunction, with the control unit. In this regard, as shown in Fig. 2, a fuel pump 64, an oil pump 66, and an auxiliary component 68 are individually driven by a drive circuit 70, 72, and 74, respectively. For purposes of illustration, the control system will be described with respect to dynamic control of fuel pump 64 and oil pump 66. It is understood, however, that the control system may be used to control operation of other or auxiliary electronic motor components 68.

[0023] Control of the fuel pump to be operational on a rail voltage exceeding its rated or maximum operation voltage will be described in particular to Fig. 3. The fuel pump drive circuit 70 includes operational circuitry to dynamically control operation of the fuel pump to be operation with an applied voltage that exceeds is rated or maximum voltage. More particularly, the drive circuit includes a microcontroller 61 that receives rail voltage feedback 63 from the rail or applied to the fuel pump 64. The microcontroller 61, from the voltage feedback 63 received, selectively switches the fuel pump, schematically illustrated as an inductor L1, between ON and OFF states via switch S1 to control power dissipation in the fuel pump. In a pre-

ferred embodiment, S1 is a MOSFET, but is contemplated that other switching components may be used. Controlling power dissipation in the fuel pump is necessary to prevent overheating and fuel pump failure.

[0024] The fuel pump is designed to draw fuel from a fuel source (not shown) and deliver pressurized fuel to a carburetor (not shown) or fuel injectors (not shown), and is rated to operate at 3 amperes DC with a nominal 12 volt input. As such, an input voltage greater than a nominal 12 volts, absent conditioning, may be damaging to and result in failure of the fuel pump. Therefore, the drive circuit 70 is controlled to prevent excessive power dissipation in the fuel pump by switching the fuel pump between ON and OFF states as a function of the rail voltage 58. That is, in accordance with pulse width modulation, the microcontroller 61 selectively switches S1 and, as a result the fuel pump between ON and OFF states, based on a duty cycle that is determined from a ratio of the rated or maximum voltage of the fuel pump and the rail voltage. For example, if the rail voltage is 60 volts and the pump is rated to operate at 12 volts, an exemplary duty cycle could be equal to 12/60 or 20%, not factoring for losses. Accordingly, the microcontroller will switch the fuel pump be-

tween ON and OFF states consistent with a 20% duty cycle and prevent excessive power dissipation. In this regard, the greater the measured voltage above the rated voltage, the shorter the pulses of the pulse width modulation.

[0025] Basing the duty cycle of switching on the rated or maximum operating voltage of the fuel pump and the rail voltage 58 output by the regulator 54 allows the fuel pump to be controlled to be fully operational and functional with varying voltages. Simply, the duty cycle changes as the value of the rail voltage changes. As such, spikes or other changes in the rail voltage are accommodated for in fuel pump operation and power dissipation management. In a preferred embodiment, the duty cycle is dynamically adjusted to maintain fuel pump operation at 3 amperes. It is contemplated that the duty cycle may be adjusted to maintain fuel pump operation at other amperages or range of amperages.

[0026] Using a ratio of rated voltage and rail voltage to determine duty cycle, the microcontroller 61 inputs a pulse width modulated (PWM) signal to switch S1 to control operation of the fuel pump 64. While it is contemplated that a DC to DC converter could be used to lower the rail voltage to a level equivalent to the pump's rated voltage, it is preferred

to regulate power dissipation through PWM. With a DC to DC converter the delay in energizing the fuel pump at engine start-up may cause a delay in pressurizing the fuel system that may be too long for efficient engine operation. Through the PWM technique heretofore described, the fuel pump is energized during engine start-up to pressurize the fuel system. Further, while manufactures of certain 12V/24V pumps/motors state that operating their pumps at higher voltages may negatively affect the operational lifetime of the fuel pump and, in particular, reduce the brush life of the motors, using the novel control of the present invention has shown through testing that such pump life exceeds that of most recreational products in which the pumps are implemented. Additionally, by powering the fuel pump with the rail voltage provided by the switching regulator, the fuel pump does not to be connected to a battery which supports incorporation of the present invention in a battery-less application. Further, it is contemplated that the engine control unit 56 may provide feedback or other data across data line 73 to micro-controller 61 to enhance the dynamic control of fuel pump 64.

[0027] As mentioned previously, a fuel pump illustrates one ex-

ample of an engine component that can be controlled to operate with an input voltage that exceeds its rated or maximum operable voltage. Another component for which the present invention may be implemented to control is an oil pump. The oil pump 66 is controlled by an oil pump drive circuit 72. Oil pump 66 is designed to force oil, under pressure, to various parts of the engine. In a preferred embodiment, the oil pump is rated to operate at 1 ampere DC on a 24 volt input. Similar to the fuel pump described above, prolonged exposure to an input voltage greater than 24 volts will cause the oil pump to overheat and eventually fail. Accordingly, the present invention includes a control system designed to control operation of the oil pump assembly on a greater than 24 volt input, but prevent overheating as well.

[0028] Control of the oil pump to be operational on a rail voltage exceeding its rated or maximum operation voltage will be described in particular to Fig. 4. Fig. 4 is schematic representation of a control circuit to regulate operation of the oil pump. The oil pump, which is schematically illustrated as an inductor L2, is shown connected to a 55 volt input. The oil pump is switched between an ON state and an OFF state by a power switch S2 that in a preferred embodiment

is a MOSFET. The MOSFET is biased by the output of a comparator COMP1 that compares a voltage measured across a sense resistor R to a voltage reference V_{ref}. Specifically, the voltage through the MOSFET is compared to the voltage drop experienced across the sense resistor by a comparator COMP2.The voltage across the MOSFET and the voltage drop across the sense resistor is input to COMP2which generates a single output indicative of scaled voltage across the MOSFET. This scaled voltage is input to COMP1and compared thereat to the reference voltage. Accordingly, if the difference between the scaled voltage and the reference voltage is within a pre-defined threshold, the comparator will provide an output at a voltage that overcomes the bias of the MOSFET and thereby cause (or maintain) running of the oil pump in an ON state. Conventionally, MOSFETS are constructed with a bias voltage or threshold of 5 volts, therefore, an output of the comparatorCOMP1 greater than 5V will bias the MOSFET in an ON state. Conversely, an output less than 5V will be insufficient to overcome the bias and, as a result, the MOSFET will switch to an OFF state. As such, the oil pump will be switched OFF as well. In this regard, through high frequency switching of the MOSFET between

ON and OFF states, current through the oil pump may be maintained relatively at its rated amperage.

[0029] In a preferred embodiment the oil pump is designed to run at 1 ampere. Therefore, the value of the sense resistor and the operating parameters of the comparator are selected to maintain operation of the oil pump at approximately 1 ampere. It is contemplated however that the present invention is applicable with an oil pump designed to operate at other amperages. Further, it is contemplated that the engine control unit 56 may provide feedback or other data to microcontroller 61 via control line 75 to enhance the dynamic control of oil pump 66.

[0030] Additionally and referring again to Fig. 2, it is contemplated that control techniques heretofore described may be used to control operation of other auxiliary components 68 of the motor. In this regard, operation of an auxiliary component 68 may be regulated by an auxiliary drive circuit 74, independent or dependent of control unit 56 via control line 77, to allow operation of the auxiliary component on a rail voltage that exceeds its rated or maximum operational voltage. The auxiliary drive circuit 74 may operate similar to the fuel pump drive circuit 70 to control power dissipation through voltage dependent

pulse width modulation of a corresponding auxiliary component or regulate an auxiliary component in a manner similar to that described with respect to the oil pump drive circuit 72.

[0031] Furthermore, while the present invention has been described with respect to independent drive circuits for controlling the engine components, it is contemplated and appreciated that the engine control unit may control operation of the engine component to operate with a voltage that exceeds its rated voltage.

[0032] Therefore, in accordance with one embodiment of the present invention, an oil delivery system includes an oil pump rated to operate within a prescribed voltage range and configured to delivery oil to an internal combustion engine. The oil delivery system also includes a voltage source having an output voltage outside the prescribed voltage range of the oil pump. The system further includes a control connected to the oil pump to operate at the output voltage outside the prescribed voltage range.

[0033] According to another embodiment, a control unit includes a drive circuit connected to an engine component rated to operate at a prescribed amperage with a prescribed voltage. The engine component is connected to a voltage rail

capable of having a rail voltage greater than the prescribed voltage. The control unit further includes a voltage sensing circuit connected to measure the rail voltage. A control circuit is provided and connected to the voltage sensing circuit and the drive circuit to control the drive circuit to maintain operation of the engine component at approximately the prescribed amperage based on a difference of the prescribed voltage and the rail voltage.

[0034] In yet another embodiment, an outboard motor is presented that includes an internal combustion engine to provide thrust to propel a watercraft and an engine component in operable association with the internal combustion engine. The engine component is rated to operate at a rated maximum voltage. The outboard motor further includes an engine control unit to control the engine component to operate at a voltage that exceeds the rated maximum voltage of the engine component.

[0035] The present invention has been described in terms of the preferred embodiment, and it is recognized that equivalents, alternatives, and modifications, aside from those expressly stated, are possible and within the scope of the appending claims. While the present invention is shown as being incorporated into an outboard motor, the present

invention is equally applicable with other recreational products, some of which include inboard motors, snow-mobiles, personal watercrafts, all-terrain vehicles (ATVs), motorcycles, mopeds, power scooters, and the like. Therefore, it is understood that within the context of this application, the term "recreational product" is intended to define products incorporating an internal combustion engine that are not considered a part of the automotive industry. Within the context of this invention, the automotive industry is not believed to be particularly relevant in that the needs and wants of the consumer are radically different between the recreational products industry and the automotive industry. As is readily apparent, the recreational products industry is one in which size, packaging, and weight are all at the forefront of the design process, and while these factors may be somewhat important in the automotive industry, it is quite clear that these criteria take a back seat to many other factors, as evidenced by the proliferation of larger vehicles such as sports utility vehicles (SUV).